Financing the Green Deal: carbon tax and green finance in a Stock-Flow Consistent behavioural model

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Issues at stake for the EU zero-carbon transition

- **Need to scale up green public and private investments** to achieve the EU climate targets (1 trillion in sustainable investments by 2030)

- **Markets are not pricing climate risk**: challenges to fill the green investment gap and preserve financial stability (Monasterolo and de Angelis 2020)

- **Carbon pricing** advocated to signal the market but insufficient (Stiglitz 2019). Need to pay attention to potential trade-offs btw eco-envir-social objectives (von der Leyen 2019)

- **Complexity** of transition towards sustainable economy and finance requires to exploit synergies across policies (von der Leyen 2019)

- **Knowledge gap**: models needed to analyse the interplay between climate policies, socio-economic and financial impacts
3 research questions

- How could a EU country foster a **just carbon free transition**, i.e. Green Deal?

- To what extent **carbon tax and green sov. bonds** financing could endogenously trigger the **green investments** needed?

- Under which conditions could **trade-offs and unintended effects** on macroeconomic performance, financial stability, inequality emerge?
Climate transition risk (stemming from a disorderly transition) is endogenous, complex and non-linear.

This means that the feasibility of making the transition depends on the risk perception of agents (gov and investors).

Agents are uncertain about the equilibrium that will prevail, and thus cannot have perfect foresight. We can have multiple equilibria.

One (optimal) policy (i.e., carbon pricing) is not enough (Stiglitz 2019).

Thus, to analyse climate transition challenges, we need models that allow to depart from one single equilibrium and optimal policy, and embed complexity and non-linearity.
**State of the art**

- **Climate Stress-test**: Investors’ exposures to climate transition risk is large and amplified by network effects (Battiston et al. 2017).

- Criticism to climate economic models (**fat tails, endogeneity, discounting**) (Pindyck, 2013; Weitzman 2009, Stern 2013)

- **Stock-Flow Consistent (SFC) modelling** (Godley and Lavoie, 2012) introduced a realistic representation of money and finance

- **SFC-behavioral models**: contribution to macroecological modeling and policy analysis by combining advantages of SFC and ABM:
  - Command and control policies: Lamperti ea. 2018
  - Prudential regulation: Dunz ea. 2019, Raberto ea. 2019
EIRIN provides a framework to analyse the **interplay of public policy, economy and finance** in the low-carbon transition.

Eirin is a SFC-AB macroeconomic model with **heterogeneous agents/sectors** (parsimonious in complexity):

- **Households** (capitalist/worker, Goodwin 1967): income source, wealth, access to finance, saving/consumption (Deaton’s buffer-stock theory)
- **Capital goods** (green/brown) based on emissions and resource intensity
- **Energy producers** (utilities brown/green, energy fossil)

**Behavioral rules** based on experimental, evolutionary economics

**Endogenously generated behaviours** and out-of-equilibrium dynamics analysed via computer simulation and sensitivity analysis
SFC Agent-Based modelling characteristics

- **Represents agents as a network of interconnected balance sheets**: allows to increase transparency wrt to drivers of shocks transmissions and impacts for better policy evaluation.

- **Departs from equilibrium conditions** and from strong assumptions on agents’ rationality and representativeness, perfect markets.

- **Provides a rigorous accounting framework**: equilibrium conditions substituted by accounting identities that hold irrespective of any behavioral assumption.

- Allows to discover **emerging** (often unexpected) micro-based macroeconomic dynamics and track **causal transmission channels**.
EIRIN added value to traditional macroeconomic models

- **Endogenous GDP growth and money creation** to support investments (Post-Keynesian, demand driven)

- **Market power** (mark up pricing on unit cost): no market clearing and no perfect competition

- **Deep uncertainty** on the future translates in adaptive expectations of agents: no optimal foresight

- **Portfolio choices** of firms, households and investors drive distributive effects (differentiated access to gains on markets)

- Conditions for public policies to **crowd in** green investments
EIRIN structure: main capital (dot)/current account flows

FINANCIAL MARKET
- Stocks green/brown
- Bonds green/brown

FINANCIAL AGENTS
- Commercial bank
  - Bonds
  - Loans
  - Reserves
- Central bank
  - Bonds
  - Loans
  - Gold

HOUSEHOLDS
- Worker
  - Deposit
  - Net worth
- Capitalist
  - Deposits
  - Shares
  - Bonds
  - Net worth
- Government
  - Deposits
  - Bonds
  - Net worth
- Foreign sector
  - Reserves
  - Net worth

ENERGY MARKET AGENTS
- Uti green
  - Deposit
  - Loans
  - Green capital
  - Net worth
- Uti brown
  - Deposit
  - Loans
  - Brown capital
  - Net worth
- MineOil
  - Deposit
  - Loans
  - Brown capital
  - Net worth

NON-FINANCIAL CORPORATIONS
- Capital goods producer green
  - Deposits
  - Net worth
- Capital goods producer brown
  - Deposits
  - Net worth

Arrows indicate flows such as: subsidies, wages, deposits, dividends, trading, coupons, taxes, consumption, and investment.
Sequence of events

1. **Policy makers** (Gov., central bank) adjust mon. policy and tax rates according to inflation, deficit, emissions targets.

2. **Production/investment/consumption plans** are made.

3. **Credit market opens.** If bank’s credit supply is lower than demand then production plans are revised downward by borrowers.

4. **Real markets open in parallel.** Mark-up pricing applied by suppliers. Transactions occur at **disequilibrium** (non-linearities, time delay).

5. **The financial market opens.** Gov. issues new brown (green) bonds to finance budget deficit (green subsidies). Investors make portfolio decisions (green/brown equity, bonds). New asset prices determined.

6. All transactions and monetary flows are recorded and agents/sectors’ balance sheets updated.
Green subsidies decrease costs of renewable investments

Green utility company $U_g$ makes investment decisions in renewable energy capacity based on Net Present Value rule:

$$NPV = -(1 - \gamma) p_{Kg} q_{Kg} U_g + \frac{p_e \epsilon_e q_{Kg} U_g}{r_D}$$

- $\gamma$: share of investment cost financed by government (green subsidy)
- $p_e$: electricity/energy price
- $r_D$: discount rate of future cash flows
- $q_{Kg}$: investment in green capital goods (e.g. solar panels)
- $p_{Kg}$: price of green capital goods
- $\epsilon_e$: energy efficiency of green capital goods (parameter)

Magnitude of green investment is endogenously generated (emerging behaviour) but timing is influenced by policy and market conditions
Asset allocation and asset pricing model

- Nine assets classes: 7 equity stocks and 2 gov bonds (brown/green).

- **Asset prices** set as **equilibrium prices** as the **ratio** between the aggregate financial wealth allocated by market players to each class and the number of class’ outstanding shares.

- **Portfolio allocation** depends on the **relative capitalization** of each asset class evaluated considering so-called “rational” (fundamental) prices (not current market prices)

- “Rational” (fundamental) prices determined according to the **discounted cash flow model** (Gordon 1959)
Rational (fundamental) asset prices

\[ \hat{p}^s_{E_a} \text{ (expected rational equity price)} \]

\[ \hat{p}^s_{E_a} = \frac{\hat{d}^s_a}{r^s_{E_a} - \hat{g}^s_a} \quad a \in \{ C, K_b, K_g, mi, U_b, U_g, BA \}, \]

- \( \hat{d}^s_a \): expected next step dividend (adaptive expectations)
- \( \hat{g}^s_a \): expected dividends’s growth rate (adaptive expectations)
- \( \hat{r}^s_{E_a} \): CB’s policy rate plus a given risk premium \( \delta \), higher when investors react to the carbon tax (climate sentiments).

\[ \hat{p}^s_{B_a} \text{ (expected rational bond price) (infinitely-lived bonds)} \]

\[ \hat{p}^s_{B_a} = \frac{c}{r^s_a} \quad a \in \{ b, g \}, \]

- \( c \): (known and fixed) coupon equal for brown and green
- \( \hat{r}^s_a \): discount rate set as CB’s policy rate plus a premium
Policy scenarios

We simulate three scenarios characterised by different financing of green subsidies to allow the country to achieve the emissions reduction targets:

- **Carbon tax** (with reinvestment of revenues in green subsidy) (Stiglitz et al. 2017, IMF 2019) *(blue)*
- **Green sovereign bonds** conditioned to green energy investments *(red)*
- **Policy coordination**: green sov. bonds and carbon tax *(green)*
- **Business as Usual (BAU)**: no policy *(black)*
Green bonds (carbon tax) improve (decreases) macroeconomic performance

(a) Real GDP
(b) Unemployment Rate
Policies stimulate renewable energy production and emissions reduction but differences across instruments

(c) Renewable Energy Share  (d) Total emissions

- Renewable energy share increases as reaction to policies (vs BAU)
- Emissions decrease the most in carbon tax scenario due worse economic performance (higher brown firms’ costs and thus lower investments and GDP growth, higher inflation)
Stock market prices reflect (worse) brown/(better) green firms’ performance

(e) Mining Company
(f) Green utility company

- Policies induce a shift from brown to green with positive (negative) effects for green utility (mining company) stock prices
- Mining company’s stock prices the lowest in carbon tax scenario due to tax costs.
Comparing Green Bonds and Carbon Tax

(g) Carbon Tax Scenarios

Carbon Tax trade-off: emissions decrease (lower brown investments, GDP, real wage) and budget neutral (debt to GDP) but higher unemployment and prices (mark-up).

(h) Green Bonds Scenarios

Green Bond: green multiplier effect (investments, GDP and thus employment). High capitalist income from higher bond yields. But no budget neutral (higher debt to GDP ratio); emission reduction effect partly offset by GDP stimulation.
Green Bonds vs. Carbon Tax: macroeconomic performance

(i) Mean CO2 Emissions

(j) Mean Debt to GDP
Policy mix: non-linear distributive effects

- Wage share increases with high carbon tax share: lower brown firms’ profits and stock prices reduce capitalists’ income
- Wage share decreases with high green bonds share: positive effect on GDP and bond yields (issuance/price) drives capitalists’ profits
- Wages increase w.high green bond share (better GDP, workers wage bargain)/decreases w.high carbon tax share (inflation, unemployment)
Conclusions

- Government policies could **signal** investors’ portfolio choices in economy and finance and foster the transition (towards a Green Deal).

- But **magnitude** of macroeconomic (GDP, inflation) and distributive effects (wage share), emissions reduction depends on type of financing (carbon tax/green bonds/mix).

- Green finance instrument have different **financial and distributive effects** (e.g. public debt/GDP): **synergies** across instruments could help mitigate **trade-offs**.

- New Klimafond **GreenFin** project explores synergies across green fiscal, monetary policies and financial regulations in EU: focus on structured and development finance (EIB).